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# THE VEGETATION OF THE BAY OF FUNDY SALT AND DIKED MARSHES: AN ECOLOGICAL STUDY.

## CONTRIBUTIONS TO THE ECOLOGICAL PLANT-GEOGRAPHY OF THE PROVINCE OF NEW BRUNSWICK, NO. 3.[1]

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(WITH SIXTEEN FIGURES AND MAPS)

AT the head of the Bay of Fundy, in the Provinces of New Brunswick and Nova Scotia, occur extensive and diversified salt marshes. In places they merge into fresh-water bogs; elsewhere, and for most of their area, they are reclaimed from the sea and in a high state of cultivation, or are in process of reclamation; and some parts remain still in their natural state. Corresponding with these marked differences of conditions are striking differences in the vegetation; and the constant operations of diking, flooding, etc., allow all gradations of conditions, and hence of vegetation, to be seen. There is here offered, therefore, an unusually favorable opportunity to investigate some phases of the dynamical relations of plants to their environment, particularly the effects of soil and water upon their forms and sizes, upon the determination of the kinds that occur in such places, and upon the succession of one kind by another. In the present paper are contained the results of the observations I have

[1] No. 1. Upon raised peat-bogs in the Province of New Brunswick. Trans. Roy. Soc. Canada II. 3[4]: 131–163. 1897.

No. 2. A preliminary synopsis of the grouping of the vegetation (phytogeography) of the Province of New Brunswick. Bull. Nat. Hist. Soc. New Bruns. 5:47–60. 1903.

The present paper was presented in abstract before the Society for Plant Morphology and Physiology at the Yale meeting, December 28, 1899.

been able to make upon these subjects during some eight weeks of field work in the summers of 1898, 1899, and 1901, together with such a summary of the origin and development of the marshes as seems necessary to an understanding of the present subject.

### Literature and other sources of information.

From the present, or indeed, from any, point of view, there is practically no scientific literature upon the vegetation of these marshes. A very brief list, of but six species, of the plants characteristic of the wild salt marsh was given by Goodwin in 1893, and references to a species or two occur in some of the papers later to be cited; but further there is nothing. Upon the geological origin, structure and economics of the marshes, however, there are valuable publications to be mentioned later. As to the literature of salt marshes in other parts of America, this also is scanty. Shaler, in two or three of his works, has given brief descriptions of the mode of formation and economics of those of the Atlantic coast of the United States, and, recently, valuable contributions have appeared by Kearney, by Harshberger, and by Lloyd and Tracy. There are references to salt marshes in Warming's and in Schimper's well-known general works, and there are papers on the salt marshes of Europe by Warming, by Flahault and Combres, and by others, and there is a synopsis of those of Germany in Drude's work.

Any account of the changes in vegetation brought about in the process of reclamation of the sea-bottoms in the Netherlands would be of interest in this connection, but such I have not found, nor have I been able to see a paper by Theen on the diked marshes of Schleswig-Holstein, mentioned by Drude (p. 390). Upon bogs, into which the marshes often merge, there is of course an ample literature, partly summarized in the first paper of this series. All of the works above-mentioned will be referred to their proper places later, and are cited in full in the bibliography at the end of this paper.[2]

[2] In the marsh country there are residents who are experts in all matters pertaining to the economics of the marshes, and from several of them I have obtained most valuable information, which I wish here gratefully to acknowledge. I am particularly indebted in this way to Mr. W. C. Milner, of Sackville, President of the Misse-

## The distribution and extent of the marshes.

The marshes now under discussion possess, as will later be shown, peculiarities which clearly differentiate them from the ordinary salt marshes so common everywhere about the mouths of tidal rivers in this country and in Europe, and hence are of a type rare if not unique. The ordinary marshes are also abundant in this region (though of small extent), particularly along the Gulf of St. Lawrence shore. Others, more like those we are considering, occur in the Bay of Fundy at Annapolis Basin, at Musquash, at Pisarinco, at St. John, at St. Martins, at Martins Head and elsewhere, sometimes diked and sometimes not. But in their complete and perfect form, the Fundy salt marshes are confined to the two heads of the Bay, *i. e.*, to Minas Basin and Chignecto Bay; and they are largest and finest in the latter. Their extent and distribution are very clearly shown upon the surface geology maps of this region, and, for Chignecto Bay, in the accompanying map (*fig. 1*). In Chignecto Bay they begin at Rougie (or Petit Rocher), just west of Cape Enrage, and thence extend irrregularly to the Shepody River; they occur in places along the Petitcodiac and Memramcook Rivers, and reach their perfection of size, economic value and scientific interest at the head of Cumberland Basin, whence they radiate up the valleys of the several small rivers of that district, the Tantramar, Aulac, Misseguash, LaPlanche, and (to a lesser extent) the Nappan, Maccan and Hebert. Largest of all is the combined Tantramar-Aulac marsh, shown in detail upon the accompanying map (*fig. 2*), and it is this, with the Misseguash marsh and the Shepody marsh, that I have studied.

The total area of the marshes with the related bogs is only approximately known. In 1895, Mr. Chalmers, of the Geological Survey, after a careful computation, estimated 34,300 acres of diked and undiked marsh in New Brunswick, of which 9,100 acres were in Albert county west of the Petitcodiac, and 25,200 in Westmorland north of the Misseguash. Mr. Monro, a profes-

guash Marsh Co.; to Mr. Howard Trueman, of Point de Bute; and to Mr. William Fawcett, of Upper Sackville. Mr. F. A. Dixon, of Sackville, has aided greatly by collecting for me seeds of many of the marsh plants.

sional surveyor who was engaged upon all of the principal surveys of these marshes, estimated in 1883 that the diked marsh (the undiked is comparatively insignificant in quantity) on the Nova Scotia side of the boundary contained 12,600 acres, while New Brunswick had on the Tantramar, Aulac and Misseguash,

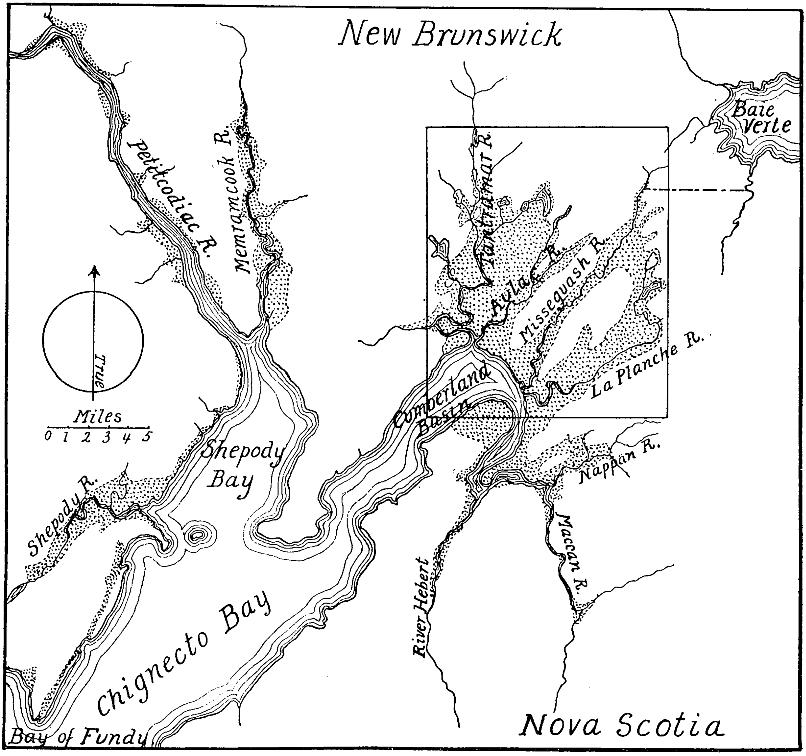


FIG. 1.—Sketch map of the marsh country, showing (dotted) the distribution of the principal marshes. The area enclosed by the quadrangle is shown enlarged in *fig. 2.*

19,400 acres. Of still unreclaimed bog lands (everywhere underlaid by marsh), there were on the LaPlanche 1,000 acres, on the Misseguash 3,700 acres, and on the Aulac and Tantramar 4,000 acres. Thus there are about 40,700 acres of marsh and bog about Cumberland Basin, of which 25,000 acres belong to New Brunswick, and 15,700 acres to Nova Scotia. Their approximate extent in this vicinity, and the relative amounts of wild

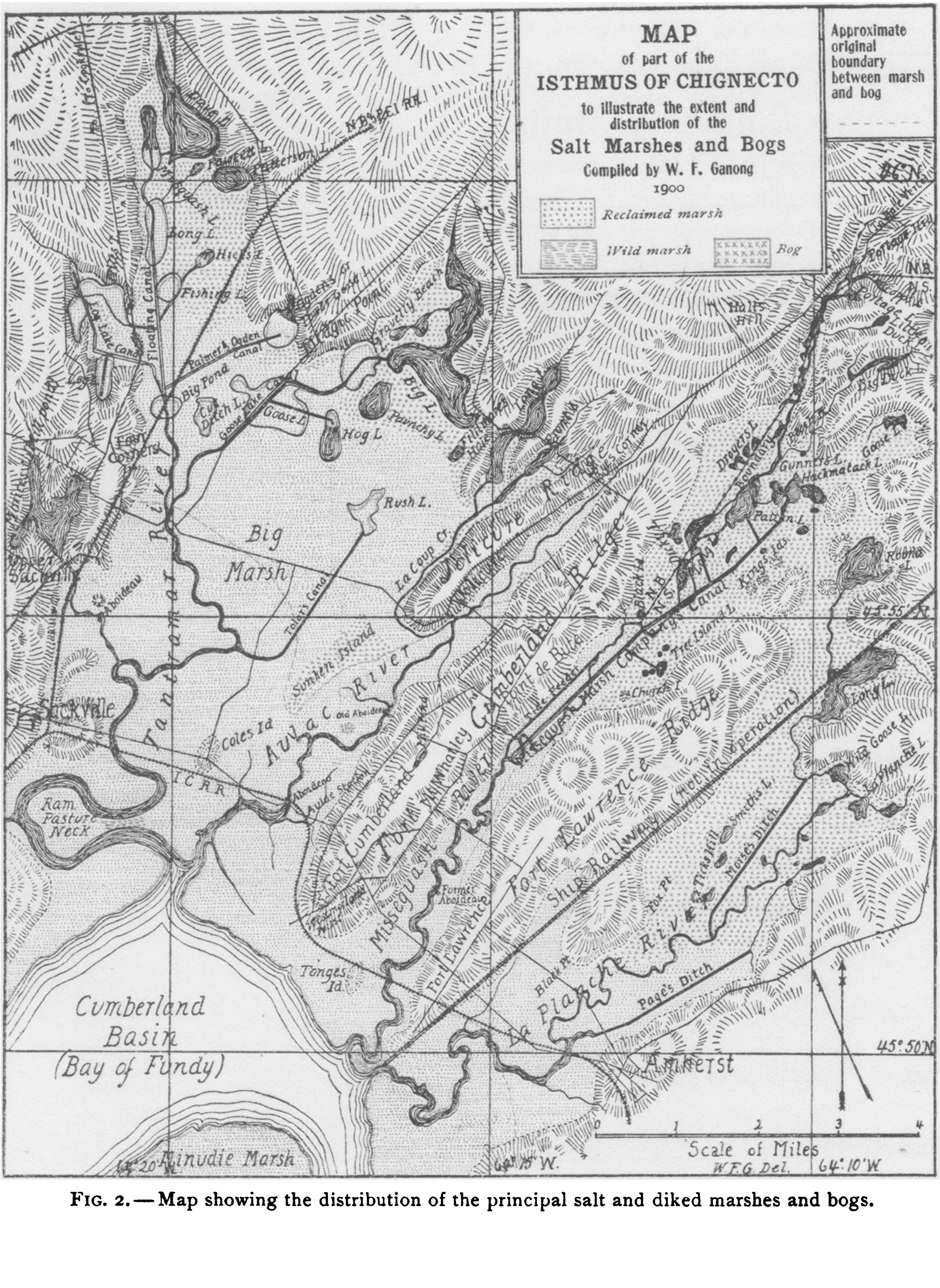


FIG. 2. — Map showing the distribution of the principal salt and diked marshes and bogs.

and reclaimed marsh and bog, together with the outlines of these marshes, may be gathered from the accompanying map (*fig. 2*) drawn to the scale of two miles to an inch. The marshes on Minas Basin are much less in area than those on Cumberland Basin, but in the aggregate there are at the head of the Bay of Fundy not far from 70,000 (or as Hamilton estimates, 80,000) acres of marshes and bogs, of which by far the greater part is diked and under cultivation. The extent of the diked marshes may be yet better understood when it is stated that, according to Shaler, the entire area of all of the diked salt marshes of the eastern United States does not exceed 5,000 acres.

## The characteristics of the marsh country.

The country around Cumberland Basin is of ancient (Palaeozoic) formations, rounded into low smooth hills and ridges separated by radiating river valleys. Among the ridges lie the marshes, seemingly level as the sea; and, like it, they fill bays, surround islands and are pierced by points. Seen from the neighboring ridges, the marshes have an aspect characteristic and beautiful. They are treeless, but are clothed nearly everywhere with dense rich grasses in many shades of green and brown, varying with the season, with the light, and even with the winds. For the most part the merging of the colors is irregular; but in places, owing to the different treatment given by different owners to their land, or to the presence of fields of grain or pasture-lots, there is something of the checkered appearance usual in highly cultivated land. The frequent ditches marked by denser growths, the rare fences and the occasional roads or railways are other signs of the operations of man. Towards the sea are narrow fringes of unreclaimed marsh, poorer in vegetation and generally duller in color, while farther back the green of the marshes gives place to the brown and gray of the bogs, which are further distinguished by irregular shrubbery and trees, and many little lakes. Nobody lives upon the marshes, but scattered upon them are many great barns, all of one and the simplest pattern, unpainted and gray from the weather, standing at any and every angle. These barns are one of the distinguishing features of the marshes, and give to

them a suggestion of plenty which is a true index of the economic condition of this region, for here are the most prosperous and progressive farmers, and the most thriving country towns in eastern Canada. Especially characteristic of the marshes are the tidal rivers which have helped to build them. As is well known, the sea here shows a great range of tides, even to over forty feet.[3] The tidal rivers, winding in the most sinuous courses through the marshes, at times run full to their bordering dikes, loaded with brownish-red mud; but the fall of the great tides sends their thick currents tumultuously out, to leave but tiny rills between deep gaping gashes of slippery mud gleaming in the sunlight. Thus too are extensive flats laid bare about Cumberland Basin. The suspended mud gives both to the rivers and to the sea a dull-red color which is a striking and a characteristic feature of the scenery of the marsh country. Not all of the rivers, however, are red, for from some of them the sea has been shut out by ingenious dams, and in each of these the banks are clad with dense green grass to near the bottom of the bed, along which winds a small fresh-water stream.

When one goes upon the marshes from the upland, he is likely to think them misnamed; for instead of the soft bottom and the rank growth associated with the word marsh, he finds everywhere a soil as firm as the upland itself, and, on the reclaimed parts, a growth of the finest grasses, luxuriant but not coarse. Indeed, a near view of the reclaimed marsh shows scarcely anything different from the best of fine-soiled upland grass land.

The marsh country is beautiful to look upon, and in addition there hovers over it the charm of a long and varied history. It was a part of the ancient Acadia and inherits the memories of

[3] The height of the tides in this region is popularly exaggerated. Careful measurements have given for Cumberland Basin a range of 38 feet for neap and of 45.5 feet for spring tides. Exceptional tides have had greater range, and the greatest on record (the Saxby tide of 1869) had a range of about 70 feet. The tides at the head of Minas Basin are ordinarily somewhat higher than in Cumberland Basin. Fuller particulars may be found in the Admiralty charts, in a "Report . . . . on the construction of a canal between the Gulf of St. Lawrence and the Bay of Fundy," Ottawa, 1874, and in a Report on a "Survey of tides and currents in Canadian waters," by W. Bell Dawson, Ottawa, 1899.

that picturesque but ill-fated country. The student in his wanderings meets with many a reminder of the ancient régime.

### The geological origin of the marshes.

An understanding of the origin and formation of the marshes is so important to the interpretation of some of the peculiarities of their vegetation, that a somewhat full account of it is needful here.

The subject was first touched upon by Lyell (in his *Travels in North America*, 1845), but received its first systematic discussion from Dawson (in his *Acadian Geology*, 1855, repeated in later editions). Subsequent accounts, with some additional facts, are given by Monro (1883), by Chalmers (1895), by Trueman (1899), and in more popular fashion by Dixon (1899); while an extremely good synopsis of the whole subject has been contributed by Eaton (1893). From the point of view of the tidal action in their formation there are papers by Hamilton (1867), by Matthew (1880), and by Murphy (1886), and of course scattered references by others.

The central fact in the formation of the marshes is this: they have been, and still are being, built in a subsiding basin out of inorganic red mud brought in from the sea by the rush of the tides, whose height is the determining factor in their height. Practically no part of their mass has been built from detritus brought down by rivers, which in this region are altogether insignificant in volume; nor has vegetation, either marine or land, helped to any appreciable extent to build them. I believe no observer of the mode of their formation could doubt that they would be as high and wide as they are today had never a plant grown about or upon them. It is these two facts, their formation out of a purely inorganic mud brought in by the sea, and the lack of cooperation of plants in their building, which differentiate them from the salt marshes so common elsewhere about the mouths of tidal rivers.

Whence, then, comes this great store of rich mud? On this all students agree; it is from the red Permo-Carboniferous sandstones forming the sides and bottoms of the channels between the marshes and the Bay of Fundy. These soft rocks are

rapidly eroded by the strong tidal currents, which, in their onward rush to the northeast, carry the detritus whirling in suspension, to drop it as their force is checked by their quiet spread over the marshes at the highest tides. Thus, the sea bottom supplies the materials, the rush of the tidal currents the power to remove, carry and lift them, and the quiet of the waters at the turn of the tide the condition allowing them to be dropped. In this way the sea is building up the land, perhaps on a greater scale here than elsewhere on the globe.[4]

The quantity of mud needed to form the marshes has been immensely great. Not only do they cover many square miles, but borings show that they can be as deep as eighty feet at least ;[5] and moreover, the marsh mud extends also everywhere under the bogs and shallow lakes clear to their utmost bounds. To supply this quantity, the channel to the bay (Chignecto Channel) must have been enormously widened and deepened, and hence it must have been very small when the process began. The sea has quarried out the channels, and the marshes are the debris. This process has been aided, or, perhaps more properly, has been allowed, by the recent subsidence of this region, of which the indisputable evidence is found in the buried forests well known to exist at several points under the marsh much below high-tide level. Dawson first described the stumps of a beech and pine forest, the wood still sound, rooted on Fort Lawrence Ridge, thirty to thirty-five feet below high-tide level. Chalmers and others have described other cases, particularly stumps laid bare, over thirty feet under the surface, in the ship-railway dock,[6] and I

[4] The power of these tidal currents in eroding the underlying rocks has been well set forth by Matthew, in his "Tidal erosion in the Bay of Fundy."

[5] Chalmers, Geological Report 1885, M, 129 : according to the same investigator however (*op. cit.* 41) this depth appears to be so great in consequence of a fault at this place. He apparently means that the downthrow took place while the mud was accumulating. The depth of 150 feet assigned to the mud at this place by Trueman, is based, as he informs me, upon the recollection of a resident as to the depth of the boring described by Mr. Chalmers. The official figures of the latter, however, make the depth somewhat under 80 feet.

[6] The ship-railway, a great work designed to transport vessels across the Isthmus of Chignecto by rail in lieu of a canal. Though over three-fourths finished, work upon it has been suspended and is unlikely to be resumed.

have myself seen such stumps in position. The soundness of the wood shows how recent the subsidence must have been. Another fact important in this connection is the presence of a bed of peat twenty feet thick under eighty feet of marsh mud, as shown by a boring at Aulac described by Mr. Chalmers. The same observer has also found that in other places the marsh mud is underlaid by post-glacial clay containing shells of species still living in this region, though in clearer and quieter waters than now prevail in Cumberland Basin, and that this clay merges without break into the marsh mud. Grouping together these facts, the history of the marshes would appear to have been as follows. At a comparatively late post-glacial period, the land must have stood much above its present level.[7] At that time the present Cumberland Basin was a shallow lake around which peat bogs were growing ; it received the waters of the seven small rivers still flowing into it, and emptied by a single narrow fresh-water channel along the course of the present Cumberland and Chignecto Channels.[8] The subsidence of the land (the same which has drowned the lower valleys of the St. John, St. Croix and other rivers of this region), allowed the tide to creep farther and farther up this channel until it reached the lake above, which it converted into a brackish, and later a salt, lagoon. At first the water would not be very muddy nor the tidal fluctuations great in the lagoon; but as the land continued to sink, the currents would become more powerful, erosion more active, and the water so muddy that marsh formation would begin around the margin of the basin and at the head of tide on the rivers. Thus, gradually, the conditions of the present day were brought about.[9]

[7] Not necessarily over 80 feet, the greatest known depth of the marsh mud, and even much less if Chalmers (Report, 41) is correct in ascribing a part of this depth to post-glacial faulting.

[8] The depth of the channel to the sea is consistent with this view. The best Admiralty chart (No. 354, "River Petitcodiac and Cumberland Basin") gives the least depth over a rock bottom as 5½ fathoms at extreme low tide, or about 80 feet below high tide. A deeper channel may however exist in the mud or sand on either side of the rock bottom.

[9] An important question arises as to whether this subsidence is still in progress. The evidence is conflicting, and the various students of the subject are not agreed. I believe it is still in progress for these reasons : first, it is still going on in other parts of

**The mode of formation of the marshes.**

So much for the origin of the marshes as a whole; we consider next the actual process of marsh-building by the sea. It may best be observed along the tidal rivers, which play an indispensable part in the building of the greater marshes. At ordinary tides the rivers do not overflow their banks nor reach the dikes at all. But at the spring tides every month they rise higher, the waters rush more swiftly, and, gathering up yet more mud from banks and bed,[10] overflow the banks, and, unless stopped by the dikes, spread abroad over the marshes. When the water thus leaves the channels, however, its speed is at once checked, and soon it comes to entire rest: it can no longer carry its burden of mud, and drops most of it. The water leaves the rivers so muddy one can see scarcely an inch or two into it; it returns, a few minues later, fairly clear. The thickness of mud deposited at a single tide varies from a small fraction of an inch on the higher places, to several inches on the bottoms of lakes which have been opened by canals to the tide.

The powerful tidal currents in the crooked rivers cause constant and rapid changes in the soft muddy banks, and all the phenomena of the wandering of rivers in a flood plain may here be seen upon an unusual scale. In fact the marshes are really the flood plains of the tidal rivers, though built by materials

Acadia (as shown in Bulletin of the Natural History Society of New Brunswick 4:339); and second, everywhere outside of the longest-built dikes the marsh is built up higher, even to two feet or more, than it is inside the dikes. Since the marsh was built as high as the tides could reach before it was diked, the land must have sunk to allow it to build so much higher now, even allowing for some sinking of the marsh through the removal of its mineral matters with the crops. Further, the ease with which the tide floods old marsh when admitted, building it up a foot or more, seems explicable only in this way. A case is known on the Tantramar marsh where a large ditch diked upon both sides was neglected, when it filled itself up with mud to a height of two feet above the surrounding marsh.

[10] The percentage of mud in the water is not so great, however, as it appears and as popularly supposed. To the eye it seems often to be little more than "liquid mud." By use of a graduated measuring glass on the end of a long cord I have taken samples from the bridges at various places, which, after settling, allowed the percentage of mud to be determined exactly. I have found the greatest amount in the rivers emptying out at low water, when it rose to an extreme of 4%, and it ranged at other times and places from that downward. At flood tide I have nowhere found it reaching 2%.

carried up their course instead of down. This wandering of the rivers explains many marsh phenomena otherwise very puzzling, such as the occasional miniature cliffs in the high marsh, and the layers of peat or blue mud (both formed only in presence of fresh water away from influence of the tide), exposed by canals, or even by the river itself, which thus reaches places formerly far removed from it.[11]

When the waters spread over the marsh, they of course drop most of their mud, and particularly its coarser parts, on and near the banks, thus building the marsh higher there than elsewhere. Hence the drainage of the fresh water, falling on the marshes as rain or draining upon them from the upland, is obstructed, and it tends to accumulate in the lowest places, viz., those farthest from the rivers, and hence near the upland or in basins between rivers. This fresh water allows the development of a fresh-water vegetation which initiates the formation of true bog, a point of immense importance in the ecology and economics of the marsh-vegetation. Again, at the head of tide in the rivers, the incoming salt water meets the outgoing fresh water and drops its sediment. Thus the rivers are tending always to dam themselves up at the contact of salt and fresh water, and they would doubtless do so completely were it not for the scouring out of the channel by the fresh water when the tide is out. The heads of the rivers, too, show another important phenomenon, viz., the level of high tide is higher there than at their mouths owing to the tendency of tidal rivers to pile up their waters on account of the inertia of their rush.[12] It hence comes about that the marsh is actually higher at the head of a river than at its mouth and the highest part of a marsh is at the

[11] It explains also the presence of concentric lines of old French dikes at Prospect Farm on the Aulac, and probably elsewhere, and the fact that the Misseguash is not now in the same position at Pont à Buot which it has on the very detailed maps of Franquet in 1754. It leads also to the occasional abandonment of pieces of marsh too small to be kept diked profitably.

[12] Mentioned in all works on tidal rivers. I have been told, as a good example of it, that the railroad levels show the high-tide level of the Petitcodiac to be higher at Salisbury than at Moncton; and Dixon and Trueman mention that at the big oxbows on the Tantramar, at very high and rising tides the water pours back over the neck into the river again.

head of the tidal parts of its rivers. This is finely shown by the levels taken on the Misseguash by the engineers of the Marsh Company, of which a condensed compilation is given herewith (*fig. 3*). Where the heads of the rivers wander, as they are particularly liable to do on account of the struggle between the fresh water and the dam at head of tide, a large part of the marsh may be thus elevated at tide-head, and in consequence the drainage above it is greatly obstructed. This results in a great accumulation of fresh water, with a consequent formation of immense bogs; and thus have originated the great bogs at the heads of the Tantramar, Aulac, Misseguash, and LaPlanche.

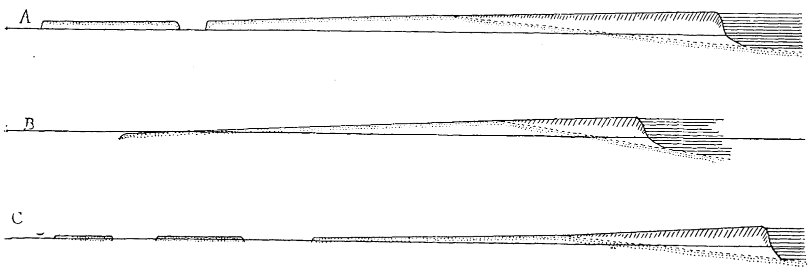


FIG. 3.—True levels on marshes and bogs determined by spirit-level; condensed from the plans of the Misseguash Marsh Co. Marsh is dotted and bog is shaded. The horizontal line is average high water in Cumberland Basin. Breaks in the marsh are where the levels ran along the river. Vertical scale 40 feet = 1 inch; horizontal ½ inch = one mile. *A*, from the Misseguash River near the railroad to Round Lake (*fig. 2*). *B*, from the La Planche River near the railroad to Long Lake; *C*, from Cumberland Basin to Long Lake.

Bogs therefore exist along the margin of upland, between rivers in the same basin,[13] and at the heads of rivers. Their extent, and their position relative to the cultivated and salt marsh may be learned from the accompanying map (*fig. 2*). In a general way the head of tide on the rivers, that is, the highest part of the marsh, marks the transition from marsh to bog; above this point, the rivers are fresh-water streams meandering through bog and expanding here and there into lakes.

The merging of the marsh into bogs is of course very gradual, and it is a well-known fact that the marsh mud extends every-

[13] Of which a perfect example occurs in the "Sunken Island" between the Tantramar and the Aulac (*fig. 2*).

where beneath the bog, even beneath the great bogs at the head of the tidal rivers. Soundings through the bog are easily made, and they show that the depth of the surface of the marsh mud from the top of the bog increases from nothing at the head of tide down to 6 or 7 feet away from the high part. Not enough soundings are available, however, to prove whether or not the slope is gradual from the high marsh to the extreme heads of the bogs, but so far as they go the soundings show this to be in general the case. This is confirmed by the water levels in the canal of the Misseguash Marsh Company. Where the canal

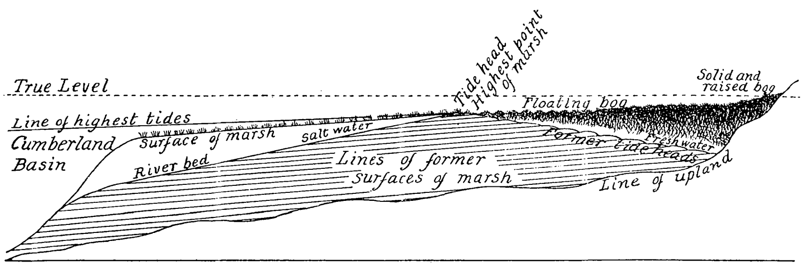


FIG. 4. — Ideal longitudinal section the marshes from sea to upland, to illustrate their origin.

passes through the highest part of the marsh near Black Island, the surface of the mud in July was nearly three feet above the water level; two miles up the bog, however, with a very slight current in the canal, the surface of the mud had dipped under the water, and the slope between the two points was perfectly gradual. It is fair to conclude therefore that the surface of the mud slopes away continuously from tide-head to the extreme distal margin of the bog. The question now arises, why this slope, which carries the bottom of the bog much below high-water level? No doubt the answer is to be found in the subsidence of the land already spoken of. Each part of the under-bog mud must at one time have been the tide-head and the highest part of the marsh; the newer tide-heads would be nearest the present one, and they would be progressively older, and hence have been carried deeper by the subsidence, the farther they are from the present one. This condition is diagrammatically represented in *fig. 4*.

The origin of the great bogs is thus made plain, but why are they mostly of the floating type? They are in fact almost entirely of this kind, though in places they are solid, and even approximate to the raised or *Hochmoor* type. They quake when one walks upon them, and a stick thrust through them penetrates from one to four feet of moss, then goes through a foot or two of water and soft organic mud before reaching the solid marsh mud. The foot or two of water seems to be fairly constant everywhere except in the shallowest parts, while the thickness of the mat of floating moss increases from the shallower towards the deeper parts, as illustrated diagrammatically in *fig. 4*. The levels (*fig. 3*) also show that the surface rises as the bog grows thicker, as is to be expected. It is a general rule in bog-formation over large basins that the floating bog is the first stage, and this is followed, as a result of growth and compacting, by solid bog, which in turn is succeeded by the raised or *Hochmoor* type. It may be a fact, therefore, that the floating character of these bogs is due to their youth—they have not yet had time to form the solid and raised types except on their oldest parts, around the margins and at the heads of the bog rivers, where such types do in fact occur. On this explanation one at first thought attributes the numerous lakes to places which the bog has not yet overgrown. But this explanation is in several respects not satisfactory. The facts seem to show that the growth of bog has been continuous from the upland outward to the marsh. Moreover, the lakes are always deeper than the surrounding bog. It seems, therefore, that there must be some positive factor tending to keep them open.[14]

[14] Possibly it may be connected with the presence in those places of a sufficient supply of salt to prevent the formation of the strongly salt-shy (halophobous) bog vegetation. As the efflorescence of salt on the mud thrown up from deep in the bog by the dredge of the Misseguash Company shows, some salt still exists in the mud beneath the bog water. This must be slowly dissolved out by the bog water, and the solution would settle towards the deepest places, which are the lakes, and might accumulate there to an extent sufficient, when stirred up by the waves, to keep them open of vegetation. The meaning of the deeper places over which the lakes lie is not so plain, but probably they represent in part portions of old river channels. This possible presence of some salt in the bottom water of the bog cannot, of course, explain the floating character of the bog, since the lower layers of vegetation are dead and unaffected by it.

A physiographic fact of some interest about the lakes may here be mentioned.

## Economics of the marshes.

I. *Crops and prices.*—When reclaimed from the sea the marshes are wonderfully fertile, and in this respect they are unsurpassed, if they are equaled, by any land in eastern Canada. They are not, however, equally good for all crops, but are best for grasses and grains, to which consequently they are almost entirely given up; root crops will grow upon them, but not to advantage. They form also extremely rich pasturage, and to some extent are used for this purpose. The grasses which grow upon the best parts are the usual upland English hay grasses, which become very tall, very dense, and of very superior quality, luxuriant but not rank, producing easily three tons and upwards of the best hay to the acre. In less well drained places, coarser grasses grow, but these too are of good value. No attempt is made to take two crops a year, though some farmers allow their cattle to fatten on the rich aftermath. No fertilizers of any sort are placed upon the marshes, and the only cultivation consists in an occasional plowing, on an average once in ten to fifteen years, when a single crop of oats is sown, after which the land is brought at once into grass again.

The fertility of the marshes depends upon two, perhaps upon three, features. First there is the presence of the substances and conditions necessary for the perfect nourishment of the crop, as shown by its luxuriance. Second, the fertility is extremely lasting. The best marsh may be cropped with unlimited yield for decades together without any return to the soil. There are places on the Aulac, which are known absolutely not to have been renovated in any way since 1827, and are believed not to have been treated in any way for fifty and perhaps a hundred and fifty years before that, which are bearing today crops as bountiful as ever. There is on this river, at Prospect farm, a small triangle, known not to have been even plowed for over forty years, which has never ceased to bear a luxuriant crop of the best English hay grasses. These are of course among the

Some of them are in contact, particularly on their northeastern margins with the uplands and have there gravelly beaches. This is no doubt correlated with the prevalence of strong southwest winds in the region, which cause a surf on the northeast shores unfavorable to the development of bog vegetation.

best places; but there are parts, particularly on the marsh longest reclaimed, which show more or less exhaustion.[15] Such marsh may have its fertility largely restored by fresh mud brought in by the sea when allowed behind the dikes. Third, the water conditions of the marsh soil are such that the vegetation is somewhat less affected by dry seasons than is that of the uplands, and a bad hay year for the uplands is not so bad for the marshes. The causes of all these peculiarities in the marsh fertility will be discussed later.

The result of this combination of good qualities is, naturally, to give the marshes a high value. Marsh situated near the towns, and well-placed for drainage, is worth upwards of $180.00 to $200.00 per acre; there are large areas valued at $100.00 an acre, while prices range, of course, from these downwards.

II. *Mode of reclaiming the marshes.*—The original marsh as built by the sea bears a sparse vegetation of typical salt marsh plants, of which only a few of the grasses, and these to a limited extent, are useful. To reclaim this marsh three things are needed: (1) to shut out the sea, (2) to wash out most of the salt, (3) to provide for the removal of the fresh water falling as rain or draining from the upland. The sea is shut out by dikes of the usual sort. These are triangular in section, built of the marsh mud itself, often with a core of stakes and brush. Against the open sea they may be six feet high, and they are protected from the wash of the waves by lines of stakes or piling and loose stones; but along the rivers they are much lower, for up the rivers the marsh itself is progressively higher. The removal of the salt takes place naturally by action of the falling rain, which washes it through the drains into the sea. It requires three to four years in newly reclaimed marsh to do this sufficiently to allow the more useful grasses to grow, and during this time there is an entirely natural succession of plants accompanying the freshening, whose kinds and sequences will presently be discussed. To allow the rain-water to drain off is all-important, not only for removal of the salt and for proper aeration of

[15] This is not to be confused with degeneration through bog-formation on account of defective drainage, a common but morphologically very different phenomenon.

the soil, but also to prevent the ever-present tendency to formation of bog plants. This drainage is accomplished by a system of open ditches, which, small and only a foot or two deep away from the rivers, are much larger and deeper near them, partly to give a fall and partly because of the greater height of the marsh there. At the outlets of these ditches on the rivers the fresh water is allowed to drain out by an arrangement that does not allow the tide to enter, namely, by placing under the dike a wooden "sluice" in which hangs a "clapper," hinged at the top and inclining outwards toward the river at the bottom (*fig. 5*). When the tide is out, the pressure of the fresh water

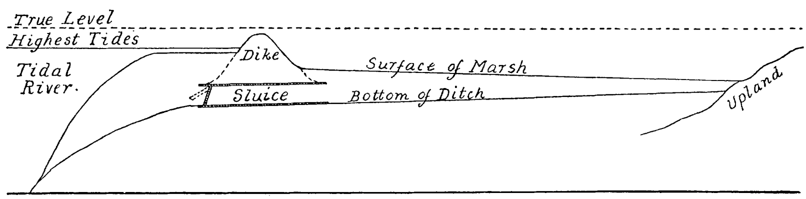


FIG. 5.— Diagrammatic cross-section through the marsh from tidal river to upland, showing a sluice.

opens this; when the tide rises its weight tightly closes it. Of course the fresh water then accumulates in the ditches, but never for long, for the sluice is not far below high-water mark. These sluices and clappers last indefinitely, apparently preserved by some antiseptic action of the salt water. A sluice of this kind is used not only in the ditches but frequently in a dike thrown across an entire river, as in the case of the Aulac. The entire structure, dike and sluice, is then called an "aboideau," and such a river is said to be "aboideaued."[16]

[16] A word introduced by the Acadians from Saintonge, France, where it is still used in the form *aboteau*. Its origin is fully discussed in the New Brunswick Magazine 1 : 225, 226, 284, 340, and 3 : 218. Naturally some other peculiar uses of words have grown up in the marsh country. Thus, the word tide is used for the salt water itself, and one often hears "let the tide on the marsh." Also the word is used constantly as a verb, as "They intend to tide the marsh," *i. e.*, to let the salt water on it, and "It was tided last year." The word ditch is used also as a verb. A large section of marsh surrounded by a single dike is called "a body." In Nova Scotia, the word dike is applied to the marsh itself (no doubt abbreviated from "diked land"), while the dike is called the "running dike," but the usage in New Brunswick is as in this paper. The word *marsh* itself is rather a misnomer and is said locally to do the country some damage by giving an unfavorable impression of its character.

The process of flooding a piece of land that has degenerated through cropping, or through bog growth as a consequence of neglect of drainage, is simple. The dikes are broken down at convenient places, and the tide is allowed to flow at will over the old marsh. Bog vegetation is killed immediately by the salt water, and it, as well as the entire marsh surface, is soon covered with several inches to a foot, or even more, of new mud. This requires from one to three years according to the situation of the marsh.[17] The dikes are then rebuilt, ditches are opened, the vegetation goes through its usual cycle, and in from two to four years it is again bearing rich English hay. This flooding, however, is by no means as extensively used as it should be, for many owners are unwilling, or cannot afford, to lose all return from their land for several years. Sometimes an attempt is made to flood and obtain crops simultaneously, by admitting only a little tide at a time, or by admitting it only in late autumn after the ground is frozen, when the grasses are little injured by it. But such compromises are considered not to pay in the end.

The struggle with the fresh water is incessant, and is the greatest care and expense of the marsh farmer. Poor drainage soon leads to the replacement of the valuable English hay by the less valuable sorts, which in turn yield to yet coarser kinds, the series ending in the appearance of useless sphagnum mosses and bog plants. Abundant and intelligent ditching is the only remedy. Farmers differ so much, however, in willingness or ability to face this problem, that areas alongside of one another under similar natural conditions with but a ditch between differ greatly, one bearing the richest English hay, and the other only the coarser kinds.[18]

[17] It seems remarkable that no attempt has been made to hasten this process by utilization of the powerful currents of the rivers to turn wheels which could pump the water and mud upon the land. Such wheels are used in other countries for irrigation purposes.

[18] There is, however, another difficulty, much more serious, which greatly hampers both the struggle with the bog and the renovation of old and exhausted marsh. The dikes are built and maintained at the common expense of a large number of owners of marsh land, and enclose a huge "body" of marsh. Owing to differences of location and of treatment, some parts of such a body come to need tiding while others do not, and

So much for the reclamation and renovation of the marshes. In addition there has grown up within a century a most important practice of reclaiming and converting into marsh both the lakes in the bogs and the bogs themselves. Its principle is simple, though the practice is by no means so. Canals are dug from the tidal rivers into the lakes, whereby the latter are drained and the tide is allowed to enter with the rich mud. In this way a lake may be entirely filled with mud and become the richest of marsh, and this has been done in the several lakes shown by the red lines on the detailed map (*fig. 2*). After the lakes have been thus reclaimed, the surrounding bog is attacked. The salt water turned upon the bog kills at once all vegetation, which compacts, sinks, becomes covered with marsh mud and gradually comes into rich marsh. Immense areas have thus been reclaimed on the Tantramar system, as shown upon the map above cited, and the process is steadily going on, while a systematic attempt is being made by the Misseguash Marsh Company to reclaim on a large scale the lakes and bogs on the Misseguash. In such operations the most constant care is needful to prevent the canals from damming and filling themselves up, and this is mainly accomplished by utilizing the outward rush of the fresh water to scour out the channels. The great aim, therefore, is to secure the greatest possible "rush of tide up, and of freshet down." There are marsh farmers who have become very expert in lake and bog reclamation, to their own profit and the good of the community. I believe this process of reclaiming bog, here practiced, is entirely unique.[19]

An important feature of the economics of the marshes is the aboideaued rivers, already explained, of which the Aulac is by

there are all gradations between. Disputes then arise among the owners of the body as to the course to be pursued, which often go so far that nothing at all is done, and great stretches of marsh suffer so severely as to become of little value. This is most markedly the case on parts of the Shepody marshes, large areas of which, capable of the highest development, are lying nearly ruined through the inability of the owners to co-operate for the common good. It would seem proper for the local legislature to interfere in such cases, where not only the interests of some owners are concerned, but also the prosperity of the neighboring region.

[19] The process is more fully described in the papers by Crawley, by Goodwin, and by Trueman, cited in the bibliography.

far the best example. An aboideau, shutting out the tide while allowing drainage of fresh water, recovers at one operation, without the expense of river-dikes, all the marsh along the river above it, and also the banks of the river and much of its bed, both of which, but especially the banks, produce the very richest of hay. At first sight it might seem wise to aboideau all rivers at their mouths, but when it is remembered that no land above the aboideau can be renewed by the tide, nor can any bog or lake be reclaimed, it will be seen that an aboideau is only profitable on streams which have no bog nor lake at their heads, and which have a soil so deep as not to need renewal. This is true of many smaller streams heading against upland, but of none of the rivers excepting the main Aulac. An aboideau upon the Tantramar would have prevented the reclamation of thousands of acres which are now productive. Naturally, therefore, there is much jealousy of aboideaus upon the part of those who own inferior marsh or bog above them, and the words of a local writer,[20] who calls them "the curse of our rivers," reflect a common opinion.[21]

[20] MR. WM. FAWCETT, of Upper Sackville, in newspaper articles.

[21] The marshes were first reclaimed by the Acadian French, who began the work in 1670 and continued it, raising much grain, until expelled by the English in 1755. They developed the methods of reclamation (of marsh, but not of bog) still in use, and many of their old dikes are still to be seen. The extent of their operations is well shown upon several maps of the time (particularly on "A large and particular Plan of Chignecto Bay," 1755), and its limits are marked by the fine dotted line drawn on the accompanying detailed map (*fig. 2*). The lands lay vacant from 1755 to 1760, after which they were regranted to New Englanders and English, and their settlement and reclamation has continued steadily to this day. In 1827 the Aulac was first successfully aboideaued, as were later the Misseguash and the La Planche, though from both of the latter the aboideaus have since been removed. No attempt was made to reclaim bog and lake until early in the last century, when a farmer of Upper Sackville, Toler Thompson, whose name is justly held in high honor in the vicinity, after long study of the tidal currents and bog levels became convinced that the lakes could be filled and reclaimed. It was long before others could be convinced, but finally a canal was dug from the Tantramar into Rush Lake (*fig. 2*) which quickly became rich marsh. Later Goose Lake was recovered, and later Log Lake (which required fifteen years to fill with mud), while Long Lake, Ogdens and others are now being filled, and thus the system initiated by Thompson is adding immensely to the wealth of this region. On the Misseguash little had been done, but five years ago a company "The Misseguash Marsh Company" was organized to attempt to do with ample capital, systematic methods, and favorable legislation, what had been done piecemeal

One other phase of the economics of the marshes remains to be mentioned. They are absolutely healthful. No malaria nor other disease is known about them. There is a local tradition that men have died from drinking the bog water; but I am told by a local physician that cases of typhoid fever are referred to and that these were probably contracted in quite another way.

## The importance of the ecological study of the marsh vegetation.

From a systematic or floristic point of view these marshes are of slight botanical interest. They contain no species that are peculiar to them, out of range, or otherwise remarkable. The plants of the unreclaimed marshes, and also of the bogs, are those ordinarily occupying such situations in this part of America, while the fully reclaimed marsh is but a good hay meadow, bearing grasses altogether like those abounding on the cultivated uplands round about. Yet from another, namely, the ecological point of view, the marsh vegetation is replete with scientific interest, for the marked gradations of physical conditions of soil and water within a limited space, and, owing to artificial changes, within a limited time, allow us a rare chance to trace upon a large scale the effects of those important conditions upon the plants, and to draw some conclusions as to the nature of the adaptation of the one to the other. It is necessary, first of all, to study carefully these, and other, physical factors to which the plants must respond; then we may trace the responses in the plants.

## The factors determining the ecological features of the marsh vegetation.

The principal ecological factors, as arranged in Schimper's comprehensive work, *Pflanzengeographie auf physiologischer Grundlage*, are the following: *Water*, *temperature*, *light*, *air*, *soil*, *animals*

on the Tantramar. This company is now vigorously at work, and it is hoped that their efforts to convert the thousands of acres of useless bog on this river into productive marsh will be entirely successful.

The best account of Toler Thompson and his work that I have seen is in an article by Judge Botsford in the *Chignecto Post* in January, 1886. Another valuable article on the history of marsh reclamation is that by Mr. Howard Trueman in the *St. John Sun* in late December, 1897.

(including the aggressive *man*). To these should be added another of great importance, *geography of the basin.*

*Water.*—Of all the factors determining plant form and distribution, this is the most important. We consider first the precipitation of the marsh country. No records are available for the immediate vicinity, but it may be inferred from the amount in places surrounding the region. Thus, according to the rainfall map published in 1899 to illustrate the presidential address (by T. C. Keefer) before the Royal Society of Canada, the mean annual rainfall is: at Moncton, N. B., $44.96^{in}$; at Truro, N. S., 43.28; at Charlottetown, P. E. I, 41.45, while at St. John, N. B., it is $47.38^{in}$. The marsh country, lying at the head of the Bay of Fundy, and directly in line with it, probably has less rainfall than St. John, but more than any of the other localities; and hence we may fix it conservatively at $45^{in}$.

As to its distribution through the year, the only available records are for St. John, where it is as shown in the following table, "for a long series of years," supplied to me by the Dominion Meteorological office at Ottawa:

| Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5.55 | 3.93 | 3.80 | 2.50 | 3.66 | 2.72 | 3.29 | 4.64 | 3.08 | 4.13 | 4.71 | 5.16 | $47.17^{in}$ |

Diminished *pro rata* for the lesser total rainfall, this table represents proportionally, no doubt, the distribution of precipitation through the year at the marshes.

It thus appears that the marshes have a precipitation ample for the development of an abundant temperate-region vegetation, and that it is distributed fairly evenly through the growing season of the year.

As to prevailing humidity of the atmosphere, there are no records available even at St. John. But since there is much cloudy weather, no little fog and mist, almost insular conditions, and very constant southwest winds blowing over the entire length of the Bay of Fundy, the humidity must be rather high.

Turning to the influence of water in another way, its mechanical effects, several points are to be noted. One is the very impor-

tant result arising from the abundant precipitation in connection with the poor drainage, leading to the formation of the immense bogs later to be considered. The presence of ground water in soil is usually important, but it here plays little or no part, as will be pointed out later. Another effect is in the scattering of seeds by means of currents. It would seem that the tidal currents in the rivers must form efficient disseminators of the seeds of at least the salt-plants. I have made a test of this by bringing back from the marshes several samples of the newly-deposited marsh mud, which the next spring were given very favorable conditions for the germination of any seeds in them, but no plants appeared. It may be that none were present in summer, and autumn samples might give a different result. There is, however, another mechanical effect of the tidal currents of considerable importance, namely, although they have built up the marshes entirely, they keep the river banks so constantly shifting, laying down mud in some places and scouring it out in others, that no vegetation is able to gain a foothold below the quieter zone near high-tide marks, excepting in the case of the curious sedge bogs, which I do not entirely understand; and these great banks are bare of all plant life excepting an occasional diatom swept from the sea. These banks and flats must be the largest areas barren of life in all northeastern America.

*Temperature.*—Next in importance to moisture as an ecological factor, is temperature. I have been unable to secure a copy

| | January | February | March | April | May | June | July |
|---|---|---|---|---|---|---|---|
| Mean highest | 28.2 | 27.6 | 34.3 | 46.4 | 57.2 | 64.4 | 68.8 |
| Mean lowest | 9.0 | 9.7 | 18.3 | 30.8 | 40.4 | 48.3 | 53.2 |
| Mean temperature | 18.6 | 18.7 | 26.3 | 38.6 | 48.8 | 56.3 | 61.0 |
| Mean daily range | 19.2 | 17.9 | 16.0 | 15.6 | 16.8 | 16.1 | 15.6 |
| Absolute highest | 50.0 | 49.0 | 52.0 | 71.7 | 75.0 | 86.7 | 88.9 |
| Absolute lowest | −21.0 | −15.0 | −10.0 | 12.0 | 27.0 | 35.0 | 41.0 |

| | August | September | October | November | December | Year |
|---|---|---|---|---|---|---|
| Mean highest | 68.8 | 63.3 | 51.8 | 43.3 | 32.4 | 48.9 |
| Mean lowest | 53.7 | 47.8 | 37.6 | 28.9 | 15.1 | 32.7 |
| Mean temperature | 61.3 | 55.6 | 44.7 | 36.1 | 23.7 | 40.8 |
| Mean daily range | 15.1 | 15.5 | 14.2 | 14.4 | 17.3 | 16.2 |
| Absolute highest | 85.0 | 85.0 | 72.4 | 61.0 | 54.5 | 88.9 |
| Absolute lowest | 43.0 | 32.5 | 21.4 | − 1.5 | −19.5 | −21.0 |

of the records kept in Sackville in the marsh country, and must turn therefore to those of St. John. The above table, based on the averages for a long series of years, is supplied by the Dominion Meteorological Office at Ottawa. Owing to well-known local conditions, the summer temperatures average lower, and the winter higher at St. John than elsewhere in the province, and this correction must be applied to the table to make it of use in estimating the conditions of the marsh country.

It is important to note further, that on the marshes themselves the snowfall is said not to be great, and often for considerable periods in winter the ground is bare. This condition, combined with the strong winds that prevail there and the total lack of shelter on the marshes, makes the winter conditions unusually unfavorable for vegetation, which must consist of plants able to endure such trying conditions. For this no arrangement is better than that of the grasses, which largely retreat to or under the ground in winter. On the other hand, at times in summer, the marshes, lying at sea level and completely unshaded, receive so strong an insolation as to become very hot, though this is never long continued.

*Light.*—The latitude of these marshes is 45° 50′ to 46°, from which the amount of light they would receive if unshaded by clouds, etc., and with a clear atmosphere may be estimated. But the full amount is much diminished by cloudy weather. No records of cloudiness are kept nearer than St. John, where the percentages for a long series of years are as follows:

| Jan. | Feb. | Mar. | April | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 53 | 54 | 60 | 55 | 61 | 62 | 63 | 62 | 53 | 58 | 60 | 59 | 58 |

Probably the cloud percentage for the marshes is not very different from this, though it would be less rather than more, say 50 per cent. for the year, 55–60 per cent. for the summer months. No records whatever for intensity of the light are available. It is important to note, however, that the marshes, perfectly level and unshaded, receive the full value of what light there is.

*Air*.—Here as elsewhere, chemically the air is hardly an ecological factor; at all events it is not a differential factor. Atmospheric pressure on the marshes, lying at sea level, is of course at its maximum, but the daily fluctuations of the barometer, as Schimper remarks, have no known effects upon the form or distribution of vegetation. Mechanically, however, as it moves in winds, the atmosphere is here important. Unfortunately no official meteorological records are available for direction or velocity, but a record of another kind is visible and unmistakable, namely, the wind effects upon the vegetation. As I have elsewhere pointed out,[22] the trees and shrubs on the neighboring ridges and in places on the margins of the bogs are strongly bent to the northeast, and show a great development of branches on that side, with an abortion on the southwest. This is caused by the very strong southwest winds which prevail here, as the residents agree, during most of the year, a phenomenon resulting from the position of the marshes in relation to the Bay of Fundy. This great bay lies northeast and southwest, and is of the form of a huge funnel. Wide at its mouth, it narrows between walls of increasing height (300 to 700 feet or more) towards its head. At Cape Chignecto the northern branch, with which we are concerned, continues and even intensifies this funnel character, ending finally in the low-lying marsh country. The great winds here are due to very much the same causes as the great tides. Every wind from a southerly direction is thus brought into a southwesterly course, condensed, strengthened, and poured over the low-lying marsh country, and the vegetation must be of a kind to endure it, for which nothing is better than the grasses.

It might be expected, as a result of the prevalence of these winds, that dunes would be formed on the unreclaimed marshes. There is, however, not the least trace of this, chiefly because the mud when laid down by the tide hardens as it dries, allowing the wind no hold upon it.

The constancy and strength of the winds on the marshes must greatly promote evaporation (transpiration) from any

[22] Bull. Nat. Hist. Soc. New Bruns. 4: 134.

vegetation there, not only in the summer, when an abundance of water is usually available for the vegetation, but in those critical periods of winter and early spring, when, owing to the low temperature of the soil, water is not readily absorbed.

Another important influence of wind upon vegetation consists in its effects upon cross-pollination and dissemination. Obviously the conditions are particularly favorable for wind-pollination on the marshes (and by that very fact somewhat unfavorable for insect-pollination), and the same is true for wind dissemination. We shall see later how much the vegetation is influenced by these factors.

[*To be continued.*]